the area of the circular zone below the aircraft at 10 km altitude is π $(6.2)^2$ or 120 square miles. For the user density referenced in section 2.1.3.1.1, this circular zone would contain about a single user half the time on the average. Assuming that the user may operate anywhere in the 16.5 MHz band, the percentage of time that operation will occur within the common 6 MHz is about 36 percent. Therefore, it is estimated that on the average there will be only one user 20% of the time within the 120 square mile zone operating within the common MSS and GLONASS frequency band. While about ten GLONASS channels are located in this common band, there are fourteen GLONASS channels below 1610 MHz. A discussion of the availability of these satellites is provided in section 2.1.3.1.4.

The previous calculation in Table 2.1.3-1 indicates that for these assumed conditions a single CDMA user should not interfere with en route GLONASS navigation operations at altitude above 10,000 m. For other conditions, such as, smaller separation distances and less fuselage blockage, co-channel operation would not be possible. However, an improved GLONASS receiving system including improved antenna patterns, improved receiver filtering plus error correction decoding could lead to increases in performance margin to accommodate operating conditions other than those stated above. GLONASS receivers should include sufficient selectivity such that they do not saturate on out-of-band signals.

In considering utilization of GLONASS for gate-to-gate navigation and providing protection to within 100 m of the aircraft as well as en route conditions, the entire GNSS must be considered with dependence upon both GPS and GLONASS satellites. Availability of these satellites is discussed in Section 2.1.3.1.4.

It should be noted that the aviation interests stated that this analysis, based on a U.S. wide average, is inadequate to demonstrate compatibility at a 95% confident level, a minimum for aviation safety services. In order for the analysis to produce values meaningful for aviation safety purposes, as a minimum the following must be changed:

- the assumed MES density should be replaced by the value which is exceeded less than 5% of the time.

- a worst case aircraft altitude based on the 95% MES distribution.

Table 2.1.3-1 - Sharing Between a CDMA User And GLONASS

Item Description	Value	Value	Units
MES Relative to GLONASS Receiver	Below	Offset	
GLONASS Signal Path			
Airborne GLONASS Receiver Elevation	10,000	10,000	m
Nominal Signal Level at Antenna	-158.5	-158.5	dBW
Antenna Gain in Direction of GLONASS	-2.0	-2.0	dB
GLONASS Signal at Antenna Output	-160.5	-160.5	dBW
Date Rate	50.0	50.0	bps
10 *Log (Date Rate)	17.0	17.0	db-Hz
Eb at Antenna Output	-177.5	-177.5	dBW/Hz
System Noise Temperature at Ant. Output	600.0	600.0	K
No, Thermal Noise Density at Ant. Output	-200.8	-200.8	dBW/Hz
MES Interference Path			
Elevation Angle to Airborne Receiver	90.0	45.0	degrees
MES Operating Frequency	1613.0	1613.0	MHz
EIRP Density per 4 kHz	-25.0	-25.0	dBW/4kHz
EIRP Density per Hz	-61.0	-61.0	dBW/Hz
Separation Distance to Airborne Receiver	6.2	8.8	mi
Separation Distance to Airborne Receiver	10.0	14.1	km
Free Space Loss	116.6	119.6	dB
Fuselage Blockage	10.0	6.0	dB
Interference Level at Antenna in 50 Hz	-170.6	-169.6	dBW/50 Hz
Antenna Gain in Direction of Interference	-5.0	-5.0	dB
Io, Interference Density at Ant. Output	-192.6	-191.6	dBW/Hz
Combined Performance			
No + Io, at Antenna Output	-192.0	-191.1	dBW/Hz
C/(No + Io), at Antenna Output	31.5	30,6	dB-Hz
Available Eb/(No + Io)	14.5	13.6	dB

2.1.3.1.3 CDMA MSS and GLONASS Sharing Analysis - General Case

The previous section analyzed the special case of ground-based CDMA MES terminal operating co-frequency with a high altitude GLONASS receiver doing en route navigation. Consider now a more general scenario. En route navigation is done over a whole range of altitudes below 1500 m to more than 15000 m. If maximum emission levels for co-channel MSS uplinks and GLONASS receiver interference immunity levels are known, then separation range can be calculated assuming free space propagation between unity gain isotropic antennas. The unity gain assumption is a reasonable upper bound given limited fuselage perturbations to the normal upward looking aircraft antenna pattern.

Table 2.1.3-2 lists the EIRP and occupied bandwidth of the five systems proposing co-channel operation with GLONASS. The power spectral density (PSD) for each was found by simply dividing EIRP by the bandwidth. The free-space separation ranges in the table are found by assuming a maximum interference level of -190 dBW/Hz for a GLONASS receiver and computing the range for the free-space loss required to reduce the PSD to that value. The -190 dBW/Hz value corresponds to a C/(No+Io) of 29 dB-Hz which is for loss of track. Note that large free-space separations are required.

Table 2.1.3-2 MSS - GLONASS Co-Channel Interference Protection Zone

SYSTEM	EIRP (dBW)	BW (kHz)	PSD (dBW/Hz)	RANGE@ -190 dBW/Hz
ELLIPSAT	4.0	1100	-56.4	70.5 km
CONSTEL	0.6	16500	-71.6	12.3 km
LQSS	-4.0	1250	-65.0	26.3 km
TRW	0.0	4833	-66.8	21.3 km
CELSAT	-9.0	1250	-70.0	14.8 km
AMSC	12.5	5500	-54.9	83.2 km

2.1.3.1.4 Availability of GNSS Satellites

In order to assure the integrity of navigational data from GNSS, RTCA has specified that a minimum of 5 satellites in appropriate geometry must be continuously in view to obtain an availability of 99.999%. Computer simulations were performed to examine the availability of the GNSS constellation based upon the orbits and operating status of the GPS and GLONASS satellites (IWG2-72). These simulations did not address the aspect of geometric dilution of precision. The most restrictive of the simulations consisted of the following constellation status: the GPS constellation consisted of 22 of the available 24 satellite maximum representing a failure of two satellites, and the GLONASS constellation was truncated to include only the 14 low frequency satellites with center frequencies less than 1610 MHz. Of these 14 satellites, failures were then assumed to have occurred in satellites numbered 3 and 9. Observations of these available GNSS satellites were made every 5 minutes over a period of about 50 days. The observations were made at a mid-latitude site in the continental United States and only satellites where the elevation angle to the satellite was 5 degrees or more were included.

The results of this particular simulation indicated that on the average 9.5 satellites were available with a maximum of 15 and a minimum of 5. Out of this 51 day period there were two occasions where the minimum GNSS availability was 5 satellites. The durations of the two periods were 8.5 and 5.5 minutes for a 14 minute total. Thus, in this study, only 0.019 percent of the time out of the 51 day period are only 5 satellites in view. Since only 4 satellites are required for navigation and a fifth satellite for integrity, it appears that GLONASS satellites operating above 1610 MHz may not be required for navigation, or for terminal approach. Therefore, operation of the GNSS system may be accommodated at extremely close separation distances between an MES and an aircraft during terminal approach since that number of available GNSS satellites meets the required minimum for computational integrity.

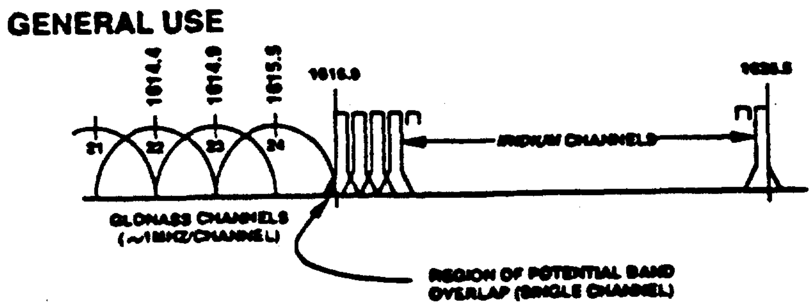
If the G-dop (dilution of precision) had been considered the number of satellites with appropriate geometry for navigation with integrity might be fewer than the results indicated. During the NRM process there was insufficient time to evaluate this situation statistically.

2.1.4 MSS/RDSS TDMA/FDMA Systems

Motorola's proposed IRIDIUM system will not operate in the same band as GLONASS. IRIDIUM system uplinks will be capable of transmitting on an FDMA/TDMA basis between 1616-1626.5 MHz. These frequencies are directly above the GLONASS frequencies. See Figure 2.1.4. Accordingly, there will be no potential for in-band interference between the IRIDIUM and GLONASS systems. Protection of the GLONASS receivers will be achieved by control of out-of-band emissions from the IRIDIUM system user terminals. A suggested limit is given in section 4.

For its contemplated narrow-band system, AMSC expects to implement the same frequency avoidance technique (~~see Section 3.4~~) by using a guardband between its uplink assignments and GLONASS channels that precludes interference.

Figure. 2.1.4 - Motorola's IRIDIUM System Frequency Plan



2.2 Potential GLONASS Interference into MSS/RDSS Satellite Uplinks

GLONASS C/A code and P code signals span the 1610-1616 MHz and 1610-1620.610 MHz bands, respectively, and present an interference threat to MSS/RDSS systems operating throughout the 1610-1626.5 MHz band. There is no regulatory limit on the power flux density used by GLONASS, and it is believed that the advance published EIRP levels for GLONASS may understate the actual power levels because the former provide only the minimum received power level (with no fading margin) that has been guaranteed to the civil aviation community. Thus, the following assessments may understate the scope of the GLONASS interference problem insofar as they are based on advance published GLONASS power levels.

The IRIDIUM system will operate out-of-band in relation to the GLONASS system. As currently configured, there will be no interference from the GLONASS system into the IRIDIUM satellite uplinks operating in the 1616-1626.5 MHz band

2.2.1 Uplinks to Geostationary Satellites

An analysis (IWG2-25) was conducted to determine the potential levels of interference from GLONASS to both AMSC narrow-band (9.6 kbps QPSK) and CDMA uplinks to a geostationary MSS satellite. For narrow-band channels operating above 1616.5 MHz, and assuming the advanced published GLONASS and GLONASS-M parameters, it was found that GLONASS would reduce the uplink carrier-to-noise power ratio (C/N) by no more than 1.1 dB for 0.01% of the time in the most affected channel through the most affected uplink beam (i.e., a beam having its half-power contour extending beyond the Earth horizon). For CDMA channels operating through the most affected uplink beam, it was found that GLONASS would reduce the uplink C/N by over 8 dB in channels below 1616 MHz for significant periods of time, which would be unacceptable. For CDMA channels operating through the least affected CONUS coverage beam (i.e., at least 10 dB more discrimination toward the Earth horizon than the worst affected beam), it was found that GLONASS would reduce the uplink C/N by about 0.3 dB in channels below 1616 MHz for significant periods of time, which would be acceptable.

2.2.2 Uplinks to Non-Geostationary Satellites

Narrow-band FDMA/TDMA LEO MSS/RDSS systems operating above 1616 MHz can be expected to inherently provide substantial frequency dependent rejection of the GLONASS emissions, such that the fade margin will not be unacceptably reduced.

In the case of MEO and LEO orbits, as proposed by other wideband CDMA MSS applicants , the susceptibility to interference from GLONASS is not problematic. Both the candidate MEO and LEO orbit altitudes are lower than the GLONASS orbit, and so the situation of interference into the MEO/LEO mainbeams cannot occur from the backlobe of the GLONASS satellite antenna. Instead the interference path is from the mainbeam of the GLONASS satellite into the back and side-lobes of the MEO/LEO satellite antennas. The control of this interference is therefore dependent on the achievable performance of the MEO/LEO satellite receiving antenna, which can be optimized to minimize this problem. Interference can still occur, mainbeam-to-mainbeam, over the Earth's horizon, but its effect will be limited, at most, only to horizon-pointing beams of the MEO/LEO satellites. The satellite receiver noise floor of MSS/RDSS systems using CDMA can be expected to be increased by GLONASS signals, but the extent of the impact depends on system design.

2.3 Potential GLONASS Interference into MSS/RDSS Handheld Terminals

The IRIDIUM system will operate out-of-band in relation to the GLONASS system. As IRIDIUM system is currently proposed, there will be no interference from the GLONASS system into the IRIDIUM handheld terminals operating in the 1616-1626.5 MHz band.

2.4 Potential MSS/RDSS Secondary Downlink Interference into GLONASS

Motorola will adequately protect the GLONASS system from any harmful interference caused by the IRIDIUM system downlink operations by the following techniques: (1) band separation; (2) controlled out-of-band emissions; (3) a guard band in limited circumstances; (4) a comprehensive analysis and testing program; and (5) international coordination.

2.4.1 Band Separation

The principal means for the IRIDIUM system to protect the GLONASS system is through avoiding co-frequency operation. GLONASS operates in the 1602-1616 MHz band whereas Motorola's downlink operations will be restricted to the 1616.0-1626.5 band. The IRIDIUM system transmits and receives on identical frequencies for each of its user terminals.

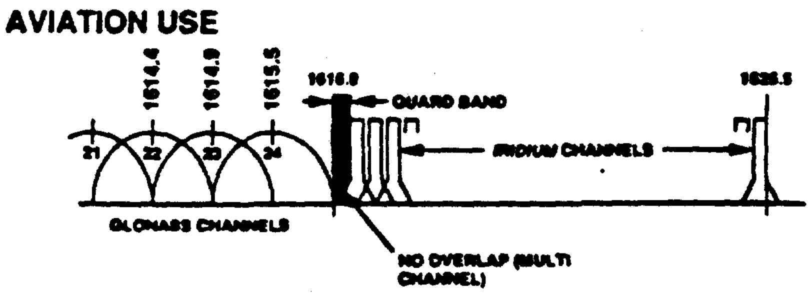
2.4.2 Controlled Out-of-Band Emissions

GLONASS will be protected from out-of-band emissions by controlling the power from the IRIDIUM satellites. A proposed power flux density limit of -141.5 dBW/sq.m./4kHz in the 1602-1616 MHz band should be sufficient to protect GLONASS in all of its operational modes. This limit can be achieved by Motorola for its out-of-band downlink emissions.

2.4.3 Guard Bands for Aircraft Operations

Aircraft that use both a GLONASS airborne receiver and an IRIDIUM aircraft unit may require a small additional guardband to protect the GLONASS receiver from interference. See Figure 2.4.3.

Fig. 2.4.3
Guard Bands for IRIDIUM Subscriber Units Used in Aircraft Operations



2.4.4 Analysis and Testing Program

To confirm that the above steps will ensure compatibility between the GLONASS and IRIDIUM systems, Motorola has initiated an analysis and testing program in conjunction with 3S Navigation, a California manufacturer of GLONASS receivers. This program involves three phases: analysis, simulation, laboratory testing and field testing.

2.4.5 International Coordination

At WARC-92, a new footnote was adopted to accompany the secondary MSS downlink allocation in the L-band. Footnote 731F requires that such downlink operations be notified and coordinated with other services in the 1610-1626.5 MHz band, including Aeronautical Radionavigation Services, in accordance with ITU Resolution 46. Based upon the foregoing techniques and programs, Motorola anticipates that such coordination can be achieved between IRIDIUM system downlinks and the Aeronautical Radionavigation Service.

2.5 Other Interference Modes

Two classes of interference scenarios between MSS L-Band uplinks and adjacent radio navigation services will be considered in this section. They are interference to airborne radio navigation in the vicinity of the final approach to the airport and interference to ground-based public safety users of radio navigation signals. The principal adjacent radio navigation service for commercial use is GPS Standard Positioning Service (SPS) centered at 1575.42 MHz. Interference from L-Band MSS secondary downlinks to GPS reception is negligible because of the weak MSS satellite signals (-139dBW/sq m) and the frequency separation involved. Following a brief discussion of GPS receiver operation, each class of interference scenarios will be described and analyzed. Different considerations may apply to GPS Precision Positioning Service (PPS) receivers, which have not been addressed in this study.

2.5.1 GPS Receiver Operational Factors

The main GPS system operational factors to be considered here are that GPS satellites orbit at 20168 km and their signals are relatively weak at the earth's surface (-160 dBW). As such, reception of GPS may be strongly influenced by the level of out-of-band emissions near 1575 MHz from MSS uplink transmitters in close proximity to the GPS navigation receiver. Normal GPS SPS receivers have interference immunity on the order of 12 to 16 dB I/S depending on the type of interference. Higher interference levels disable the GPS receiver tracking loops working on previously acquired satellite signals or prevent the receiver from acquiring a new satellite signal. At best navigation accuracy is degraded; at worst navigation fails altogether.

2.5.2 MSS Interference to Airborne GPS Navigation

The first class of scenarios involves interference to airborne GPS navigation receivers from MSS transmitters in the vicinity of an airport final approach path. This interference may influence GPS operation in two different ways. One way is through disrupting proper reception at the ground-based differential GPS receiver site. The other is through disrupting GPS reception at an aircraft in final approach. The use of differential GPS for final approach navigation is necessary to achieve the required position accuracy at the decision height. For differential GPS operation, the ground-based receiver site makes measurements of its apparent position by GPS which are compared against its accurately surveyed position. It then sends its position error corrections by a data link to other GPS users in the near vicinity. The principle measurement errors which are removed are deliberate selective availability dithering of the C/A code and ionospheric delay errors. The resulting navigation accuracy is on the order of a few meters for differential mode compared to 100 m for standard C/A service. Because the fixed site serves many potential airborne GPS users in a 40 km radius of runway threshold, interference to its operation could have serious consequences for final approach navigation. Physical separation and out-of-band emission control of the MSS uplink transmitters are the principal means of interference mitigation.

The other way in which MSS can interfere with airborne GPS navigation is directly to the satellite-to-aircraft link in an area near the runway threshold. The geometry for this general scenario is different than that for the ground-based, fixed site differential receiver. The aircraft GPS antenna is most likely at a higher altitude than the MSS transmitter (at least 50 m). In addition, a top-mounted aircraft antenna would likely be shadowed to some degree by the wings and body from a ground transmitter at the closest point directly under the aircraft antenna. Thus the interfering signal coming in from below would suffer with respect to desired satellite signals coming from above by the aircraft antenna directivity ratio (a few dB). At points off to either side of the standard 3° aircraft glidepath the slant range to the MSS transmitter increases as interference signal angle of arrival becomes less negative. The R^{-2} factor will eventually dominate over the antenna directivity factor. Even with the effects of aircraft pitch and roll it is difficult to imagine a scenario for which the interferer has better than parity with the satellite for antenna directivity. It should be noted, however, that the aircraft at nominal approach velocity on a 3° glidepath takes about five minutes to descend the last 1000 m of altitude when it is increasingly susceptible to interference.

2.5.3 MSS Interference to Ground-Based GPS Navigation

Interference to airborne GPS navigation is clearly of great importance as a potential safety hazard. Ground-based GPS navigation by public safety vehicles such as police, fire, and ambulances represents an important GPS use which deserves some interference protection also. In this class of scenarios the MSS uplink transmitter antenna and the GPS receiver antenna are quite likely at the same height and separated by only a few meters (e.g. highway lane width). Although the distances are smaller than in the airborne scenarios, the relative vehicle motion should bring the public safety vehicle within the minimum spacing for only a short time. This motion effect should allow some improved rejection through navigation solution averaging in the GPS receiver. Additional out-of-band rejection in the MSS transmitter is also desirable.

2.5.4 MSS/GPS Interference Numerical Example

To establish a frame of reference for the physical separation at which the emission level of an INMARSAT-C mobile satellite terminal would fall below the GPS loss-of-track threshold, consider the following numerical example. The terminal emission spectrum is given in Fig. 2.5-1. The spectrum should be translated down by 16.5 MHz so it corresponds to MSS band operation. Emission at 1591.5 MHz on the figure corresponds to 1575 MHz when translated. If unity gain, isotropic, free- space propagation is assumed between the mobile transmitter and the GPS receiver, then at 1575 MHz

Path Loss (dB) = 36.4 dB + 20*log(R), {Eqn 1}

where R is the separation in meters. The emission level in a 1 Hz bandwidth (Ie) is found by subtracting 34.8 dB from the plotted value, I, and is assumed to be effectively broadband noise to the GPS receiver. The carrier-to-total noise density ratio threshold for maintaining track in a GPS receiver with interference is

C/(No+Io)= 28 dB-Hz. {Eqn. 2}

The effective input thermal noise power density No= -198 dBW/Hz for a nominal receiver. This value assumes 100 K effective antenna temperature, 2 dB of antenna and cable ohmic losses, and a 555 K receiver/processor input temperature. For a -160 dBW satellite signal,

C/No= 38 dB-Hz. {Eqn. 3}

Therefore, comparing {2} and {3} yields (Io+No) = 10*No, which gives Io = 9*No or

Io= -198 dBW/Hz +9.5 dB = -188.5 dBW/Hz {Eqn. 4}

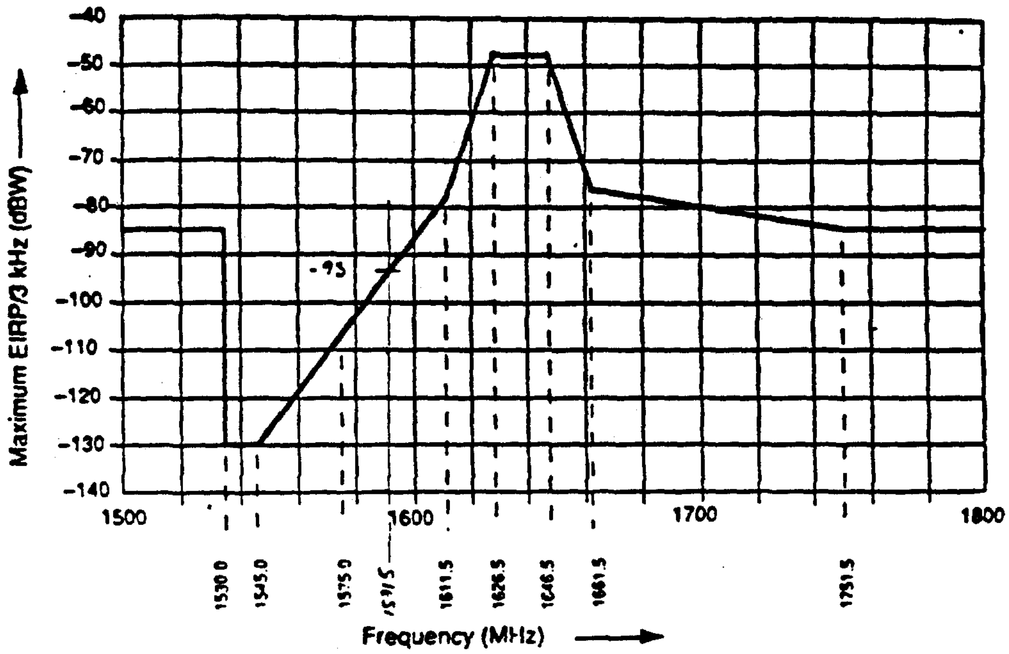
With an emitted interference level of -93 dBW in a 3 kHz band (Ie= -127.8 dBW/Hz) from the plot at 1591.5 MHz, Equation 1 gives the spacial separation to achieve the path loss (Ie-Io) (dB)

(-127.8+188.5) dB = 36.4 +20*log(R)

or R= 10**((60.7-36.4)/20) = 16.4 meters separation.

This value may represent an upper bound to an actual MSS/GPS scenario if MSS out-of-band emission levels are lower by virtue of in-band EIRP levels lower than the +12 dBW of an INMARSAT-C type terminal. Some added margin should be allowed for the GPS receiver worst case interference immunity, however, which would tend to increase the required separation. Also the GPS receiver minimum C/No for acquisition is higher (32 dB-Hz) than for loss-of-lock. Approximately 5 dB lower emission levels are required to allow acquisition. For example, the combination of 10 dB lower emitted noise from an MSS transmitter and a 5 dB lower receiver immunity limit would result in a 44% decrease in separation distance.

Figure 2.5-1
INMARSAT-C Terminal: S.D.M. Mask for Transmitter Spurious & Noise E.I.R.P Density



3. **Approaches to Sharing Between GLONASS and MSS/RDSS Systems**

IWG2 recognizes the existence of aeronautical radionavigation systems operating in the 1610-1616 MHz band (namely, the Russian GLONASS system), and the importance to the aviation community of protecting GLONASS. Under the Radio Regulations, the 1610-1626.5 MHz band is in effect shared on a co-primary bases by the mobile satellite service/RDSS and aeronautical radionavigation service.

IWG2 was unable to agree on an interpretation of RR 731E. RR 731E establishes a limit on the maximum uplink e.i.r.p. density which can be radiated by a mobile terminal operating co-channel with GLONASS. RR 731E further states that MSS stations shall not cause harmful interference to, or claim protection from, stations in the aeronautical radionavigation service, stations operating in accordance with the provisions of No. 732 (GLONASS), and stations in the fixed service operating in accordance with the provisions of No. 730. However, the last sentence of RR 731E does not apply to radio determination satellite service.

In this last regard, the Radio Regulations define harmful interference as "interference which endangers the functioning of a radionavigation service or other safety services, or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with these regulations." In other words, harmful interference to GLONASS may be considered to occur when radionavigation cannot be performed as a result of the interference.

IWG2 faced two difficulties in interpreting RR 731E. First, it could not agree on the interpretation of the uplink e.i.r.p. limit with respect to the prohibition on causing any harmful interference to GLONASS. The issue is whether operating at or below the e.i.r.p. limit satisfies the MES station's obligation to protect GLONASS from harmful interference, or whether the obligation to protect GLONASS goes beyond this specified limit. And second, the more general issue, was what level of interference is considered to be harmful to GLONASS.

Another component of this issue is identifying a protection limit with reference to the design characteristics and test requirements of GLONASS receivers. These characteristics are currently developed by RTCA and the Airlines Electronic Engineering Committee (AEEC).

The process for developing GLONASS receiver characteristics is being conducted by the FAA, RTCA and AEEC with a view towards standardizing electronic equipment and systems for aviation. Participants largely are air carriers, airframe manufacturers, avionic equipment manufacturers, service providers, and aircraft owners and operators; the process is open to the public. The current specifications for these receivers were developed with a view to protection from out-of-band emissions from a variety of sources including INMARSAT terminals used for aviation communications (1646.5-1656.5 MHz). The original characteristics, published in March 1992 were not developed to address the possibility of operating in a co-channel environment with MSS. The process of updating receiver characteristic revealed that greater levels of immunity to interference could be achieved, however, these are not sufficient to permit most co-channel operations with MSS.

As discussed above, the aviation community plans to use GLONASS along with GPS, for en route navigation, terminal operations, non-precision and precision approach, landing, departure and surface operations such as taxiing to and from airport gates. These users plan to use receivers that utilize both GLONASS and GPS signals in concert in the same avionics unit. In order to achieve its target levels of integrity and availability (99.999% of the time), the aviation community developed interference rejection criteria based on current specified receiver performance (ARINC Characteristic 743A).

In Section 2 a scenario was posited whereby protection of these receivers on airplanes operating at large separation distances, e.g., greater than 12,000 m. slant range for the MES, may be able to be achieved. Protection in this very limited scenario is not viewed as adequate to allow for the full range of MSS and radionavigation functions.

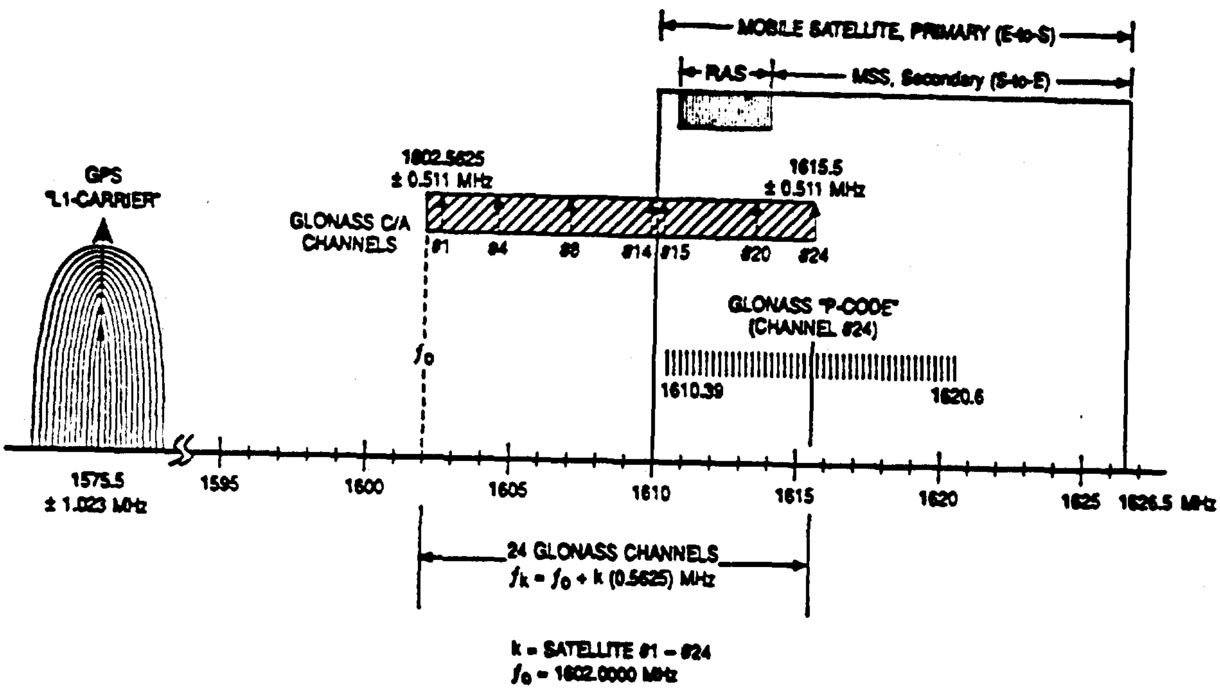
With these requirements in mind, MSS systems based on current technology cannot meet the MES e.i.r.p. density levels (i.e., less than or equal to -78 dBW per 1 MHz for co-channel operation) specified by aviation for protection of aeronautical radionavigation (e.g., GLONASS) at spacings as little as 100 m.

Based on the foregoing and the respective technical and operational requirements of the aviation and MSS interests, it appears that the prospect for compatible co-channel operations in the 1610-1616 MHz band are limited. IWG2 nevertheless has identified several potential actions which may be used to improve such prospects.

3.1 Possible GLONASS Actions to Improve Sharing Environment

The following figure 3.1-1 depicts the current frequency plan of the GLONASS system:

Figure 3.1-1
Frequency Plan of GLONASS (and GPS) in Relation to MSS Allocations in the 1610–1626.5 MHz Band



Unlike GPS, which uses one universal carrier frequency with different coding for each satellite, each GLONASS satellite utilizes a separate, individual downlink transmit carrier frequency. With 24 satellites in the full GLONASS constellation, there are planned to be 24 discrete frequencies in use simultaneously. However, in the satellites currently under construction for GLONASS replenishment, the satellite downlink frequency assignments are programmed by telecommand from the ground control station. Thus, it is assumed that each of the new GLONASS-M satellites has the capability of operating on any of the 24 frequencies between 1602 and 1615.5 MHz.

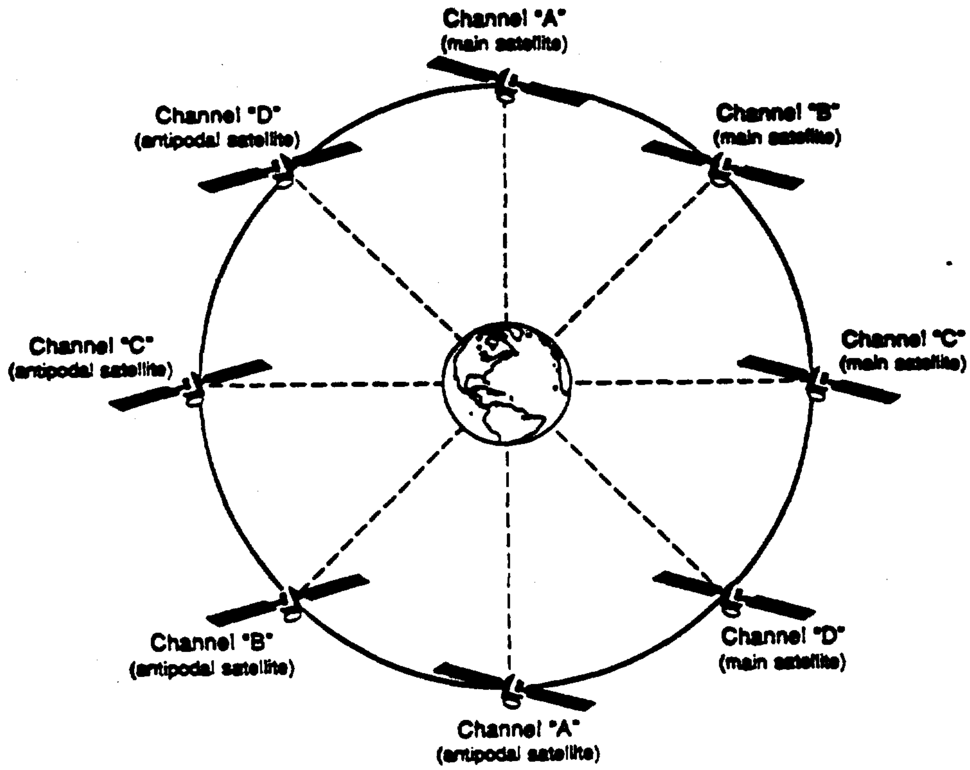
Because of this frequency agility, it may be possible that some of the satellites, while on opposite sides of the earth, could use the same frequencies without causing self interference.

3.1.1 Reconfiguration Scheme: GLONASS ReUse Of Frequencies on Antipodal Satellites

As shown in Figure 3.1-1 GLONASS, when fully implemented, will use 24 discrete downlink carrier frequencies running from 1602.5625 to 1615.5 MHz, with each carrier modulated at a 511 bit/s chipping rate. The binary bit stream modulating the carrier at that rate is the Modulo-2 sum of the ranging code, navigation data.and auxiliary code pulses. The carrier components of the transmitted navigational signal (carrier frequency, ranging code, navigation data, code pulses) are all derived from the same onboard frequency source on each GLONASS spacecraft. The most beneficial reconfiguration of the GLONASS frequency plan--from the point of view of both U.S. aviation and MSS interests--would be to reconfigure the GLONASS 24 operational satellites to operate on 12 carrier frequencies vs. 24. This plan was broached to the former USSR several years ago by U.S. aviation officials; and, while rejected then, might be given favorable reconsideration in view of current political and economic climate associated with plans to aid the Russian Federation's conversion to a market-based economy.

In this scenario, antipodal GLONASS satellites could be assigned the same carrier frequencies. As shown in Figure 3.1-2, this results in each orbital plane of 8 satellites occupying only 4 carrier frequencies, instead 8 which are used now. In this way the entire 24-satellite constellation would utilize 3 x 4 = 12 carrier frequencies. As seen in Figure 3.1-1, there is spectrum for 14 GLONASS carrier frequencies in the band from 1602.5625 to 1609.7750 MHz. Thus, this plan would allow the full-up GLONASS system to operate below 1610 MHz. This reconfiguration allows GLONASS to avoid all co-channel interference from MSS terminal uplinks; further, with appropriate filtering of the GLONASS transmitted signal, it has the very beneficial result of avoiding in-band interference from GLONASS into the Radio Astronomy band at 1610.6 to 1613.8 MHz.

Figure 3.1-2
Schematic of GLONASS Reconfiguration to 12 Carrier Frequencies, Employing Frequency Reuse on Antipodal Satellites
(One of Three Orbital Planes Depicted)



In addition, this approach would provide other benefits to the aviation and INMARSAT communities. With GLONASS operations limited to 12 channels below 1610 MHz, exotic filtering in the AERO SATCOM terminal diplexer needed to protect GLONASS receivers on the same aircraft from lower order intermodulation products when the terminal operates with multi-channel voice carriers can be eliminated, making for a more cost-effective SATCOM installation. This would ease installation of SATCOM terminals on GLONASS equipped aircraft. The SATCOM terminal is an important element of aeronautical communication and surveillance in the air traffic control system.

Working Group 2's analysis indicates that GLONASS could successfully operate and achieve its mission with the 12-channel plan. Due to the frequency agility inherent in the new GLONASS-M spacecraft being built, it should be possible to re-assign the frequencies from the 24-channel baseline frequency plan to the proposed 12-channel plan without affecting the design of the GLONASS satellites.

However, the older generation of Russian-made GLONASS receivers, type ASN-16, have a relatively primitive, single-channel signal processing architecture. Due to its older design, the ASN-16 probably cannot be used with the 12-channel/antipodal reconfiguration of the GLONASS system. Most of these 1500-2000 units are being used by Russian aircraft; and as such, would require replacement. Nevertheless, the ASN-16's are no longer being produced and are slated for replacement by the more modern ASN-21 GLONASS receivers. One approach would be to transfer the more sophisticated, state-of-the-art technology of U.S. GPS/GLONASS navigational equipment manufacturers to the Russian Federation, so that ASN-21's could be modified to work with a 12-channel/antipodal frequency plan.

The modification of a GLONASS receiver to perform properly in antipodal operation is essentially a modification of a portion of the receiver's digital information processing algorithm; no modification to the RF circuitry should be required, because the satellites in an antipodal configuration use the same modulation waveform as in the present GLONASS system - only the carrier frequencies change.

The data content of the GLONASS NAV message makes the modification to the receiver a relatively straightforward one. Essentially, the only modification is to change the values in the look-up table in the receivers firmware which enables the receiver to determine the frequency channel on which to search for a given satellite. Once the receiver begins acquisition of the satellite's signal, subsequent digital processing is unaltered from that in the current GLONASS system. Only rarely would the receiver need to immediately acquire the antipodal partner of a satellite which has just gone below the receiver's horizon. In normal conditions, six or seven GLONASS satellites are above the receiver's radio horizon (generally considered to be 5-8 degrees above the visible horizon) at any given time. With a full GLONASS satellite constellation aloft, 10-11 satellites would be visible. A multi-channel receiver appropriate for aviation use will continuously monitor not only the four or five satellites it uses to construct a given position fix, but also (in its background processing using the catalog broadcast from all GLONASS satellites) is able to evaluate all combinations of currently visible satellites. This will enable the receiver to automatically acquire a new satellite and use that satellite's NAV-message data to replace that of a previously tracked one. The receiver is indifferent to which of two antipodal partners is currently being tracked and no performance degradation results.

3.1.2 GLONASS Frequency Shifting Plan

Another approach considered by Working Group 2 is to shift all GLONASS assignments to frequencies below 1610 MHz, but still above the adjacent GPS frequency assignments. The highest frequency GPS carrier is 1575.42 MHz, and the first null of the P-code (10.23 MHz chip rate) is at 1585.465 MHz. Assuming that GPS receivers can tolerate some interference from a GLONASS lower sideband in the frequencies beyond this first null, making a similar assumption about GLONASS P-code (5.11 MHz chip rate), the lowest frequency GLONASS assignments can be moved downwards to start at 1585.65 + 5.11 = 1590.76 MHz. This shift of about 11.5 MHz is more than the necessary minimum to move GLONASS out of the MSS/RDSS band, even when GLONASS broadcasts P-code on its highest frequency carrier. The situation may be further improved by using Channel 0 (currently used only for initial testing of new GLONASS satellites) as an operational C/A code.

It should be noted that any major shift in GLONASS frequencies could require system redesign.

3.1.3 Enhanced Receiver Standards

With the advance notice that MSS systems will be deploying satellites in the 1610-1616 MHz band by 1997, the aviation community, including the GLONASS and GPS and aeronautical receiver manufacturers, should be encouraged to modify GLONASS receiver performance standards in order to reduce GLONASS's vulnerability to in-band interference from MSS. It is noted that the AEEC has recently proposed more stringent standards (from 13 to 21 dB for interference rejection).

It is also noted that this approach is unlikely by itself provide enough additional rejection to enable MSS systems to protect GLONASS to the degree desired by aviation. Nevertheless, it may be helpful if employed in conjunction with other interference mitigation techniques.

3.1.4 Revision of Proposed Aviation Reliance on GLONASS as a Component of GNSS

The aviation community has stated that it must use both GPS and GLONASS to provide the necessary integrity and availability it requires for a GNSS on which reliance is placed. IWG2 suggests that the aviation community consider alternatives to the sole means reliance on GLONASS. Such alternatives include additional GPS satellites, use of navigational packages on geostationary satellites to validate and supplement GPS, and other means of augmenting GPS.

If MSS is to operate on a co-channel basis with GLONASS, the aviation community must diminish its anticipated reliance on this system as a part of the GNSS.

3.2 Maximum Permissible E.I.R.P. Density from Handheld Terminals

The purpose of defining a maximum permissible e.i.r.p. or e.i.r.p. density from MSS terminals operating co-channel with aeronautical radionavigation services such as GLONASS is to assure that the user of GLONASS will have sufficient margin in his receiver C/(N+I) or C/(No+Io) to permit successful operation.

At one end of the spectrum are the values adopted at WARC-92 and contained in Footnote 731E (-15dBW/4kHz). It has been noted above that adherence to this value will protect GLONASS receivers only in the limited case of wide separations (in excess of 12,000 m.). At the other end are the protection criteria which aviation has specified as required to protect GLONASS receivers within as little as 100 m. separation.

Because of the wide disparity between the two communities requirements, the specification of an e.i.r.p. uplink limit will not resolve the sharing issue.

3.3 Protection Zones

The United States aviation community, in the RTCA Task Force Report on the Global Navigation Satellite System (GNSS) Transition and Implementation Strategy, has expressed interest in using GLONASS as a part of the GNSS for "gate-to-gate" navigation. The U.S. aviation community states it needs total assurance that no harmful interference would occur from MSS transceivers into GLONASS receivers in this scenario.

As discussed above, MSS systems operating within the limits prescribed in Radio Regulation 731E should be able to protect GLONASS receivers for limited high altitude en route navigation.

Another potential means of protecting GLONASS from harmful MSS uplink interference addressed by IWG2 is the use of exclusion or protection zones around such critical GLONASS operational areas as the final approach paths into airports, the approach navigation signal capture points and en route navigation paths. Given the spatial separations for the various CDMA systems listed in Table 2.1.3-2, (i.e.from 12 to 83 km), fixed protection zones around en route paths, signal capture points, and final approach paths would exclude co-channel MSS use from nearly all of CONUS (see IWG 2-76).

If the protection is provided through the use of beacons aboard the aircraft, the MSS operation area near en route paths would be significantly increased. This solution, however, is impractical due to the high cost of beacon installation and maintenance. A high reliability, dual frequency (L-/S-Band) beacon system would be needed on all aircraft which intend to use GPS/GLONASS as a primary navigation system. Not only would Air Transport category aircraft need the dual frequency beacon system, but also large numbers of General Aviation aircraft, as well, which are much less able to absorb the extra cost.

In conclusion, the use of protection zones and associated beacons to eliminate co-channel MSS uplink transmission, when insufficient separation exists between MES and the GLONASS receiver, appears difficult and expensive.

3.4 Repositioning of MSS User Frequency

Another possible approach to protecting GLONASS would be to utilize an avoidance mechanism under the control of the MSS system operator. This mechanism would prevent MESs from transmitting on specific GLONASS frequencies in the 1610-1616 MHz band. However, the approach requires accurate information on the position of the MES before assigning it to transmit on a channel in the 1610-1616 MHz band. This approach works in the following way:

MESs will request a channel, using a control frequency above 1616 MHz. The MES would transmit its position along with its channel request. The gateway, after it receives this information as to the user's position, will utilize a computerized up-to-date "look up" table to analyze the location, ephemeris and frequencies of all GLONASS satellites. This will determine whether a GLONASS satellite or satellites operating in the 1610-1616 MHz band are coming into view of the MES. If such a satellite or satellites are coming into view, the gateway will not assign the channel used by the

GLONASS satellite(s) to that MES user. In this way, no MES will simultaneously utilize the frequency of a GLONASS satellite that could conceivably be used by a GLONASS receiver on-board an aircraft when calculating a position fix. The MES will have to include controls for changing frequency in the event that a GLONASS satellite using the same frequency as the MES comes into view during an MSS transmission. Since this mechanism is a critical element in the protection of GLONASS from harmful interference, the detailed design and implementation of this mechanism should be coordinated with the aviation authority.

While admittedly a complicated mechanism, additional study of this approach may be warranted.

4. Conclusions and Recommended Rules

4.1 Reconfiguration of GLONASS Frequency Plan

Informal Working Group 2 (IWG2) believes that the best solution to enabling both MSS and GLONASS to operate compatibly without operational constraints is to effect a reconfiguration of the GLONASS frequency plan. As discussed in Section 3, IWG2 believes that this reconfiguration can be achieved without requiring modification of the GLONASS spacecraft design and without compromising the operational objectives for use of GLONASS as stated by the aviation community. In addition, this approach will also resolve much of the current interference from GLONASS experienced by radioastronomy.

To achieve this objective, the FCC, along with other appropriate U.S. government agencies, should initiate discussions with the Russian administration concerning this reconfiguration. Such an approach should also be made an integral part of any U.S.-Russia discussions concerning Article 14 coordination of GLONASS-M.

Absent an agreement on the part of the Russian Administration to shift or fold these frequencies as proposed in Sections 3.1.1 and 3.1.2, lesser adjustments to the GLONASS frequency plan should be pursued by the United States.

4.2 Enhance GPS System and Reduce Need for Protection of GLONASS

The aviation community, within this proceeding, has emphasized its desire to use the GNSS as a "sole means" navigation system, for multiple applications. The aviation community should be asked to explore all possible alternatives to provide it the integrity and availability it seeks in the GNSS, including enhancement of the GPS system through the deployment of more GPS satellites, and use of other facilities. If protection of GLONASS to the extent sought by aviation is mutually exclusive with the operation of MSS systems, IWG2 suggests that the FCC work with the aviation community to identify a means to use GPS with non-GLONASS augmentations to meet aeronautical navigation requirements.

4.3 Actions Regarding the 1610-1626.5 MHz Band (Earth-to-Space)

IWG2 recommends that the Commission adopt the uplink e.i.r.p. density limits contained in RR 731E. Adopting these limits is necessary to enable the proposed MSS systems to be brought into use and support an important and beneficial U.S. initiative to provide mobile communications.

However, it is noted that the aviation community believes that adherence to this limit will not assure protection to GLONASS for most aeronautical applications. If the Commission were to accept the aviation community's stated requirements for use of GLONASS as a component of a "sole means" GNSS, the co-primary MSS allocations in the 1610-1616 MHZ band would be effectively nullified because of the disparity between aviation's protection requirements and practical e.i.r.p. levels needed to support satellite uplinks.

The FCC's adoption of such a rule does not imply protection of the GLONASS system to the extent desired by the aviation community.

4.4 Actions Regarding the 1613.8-1626.5 MHz Band (Space-to-Earth)

IWG2 finds that allocating the 1613.8-1626.5 MHz band in the space-to-earth direction on a secondary basis is consistent with sharing with GLONASS. In order to facilitate the operation of the secondary downlink in this band in a manner which will not cause harmful interference to GLONASS, space stations which utilize this band for downlink shall not exceed a power flux density of -141.5 dBW/m^2-4kHz in the GLONASS operation band.

4.5 Restriction of Use of Mobile Earth Stations on Aircraft

In order to protect operations of GLONASS receivers and other navigational avionics on-board aircraft, the Commission should adopt a rule which prohibits the operation of mobile earth stations used with geostationary and non-geostationary satellites on civil aircraft, unless the MES has a direct connection to the aircraft Cabin Communication System.

4.6 Out-of-Band Emission Limit Recommendations

Mobile units which operate with mobile-satellite systems utilizing any portion of the 1610-1626.5 MHz band shall limit their out-of-band emissions so as not to exceed an e.i.r.p. density of -70 dBW/1MHz averaged over any 20 ms period in any portion of the 1575.42 +/- 1.023 MHz band for broadband noise emission. For any discrete spurious emissions in the same band, i.e., bandwidth less than 600 Hz, the e.i.r.p shall not exceed -80 dBW. With regard to GLONASS, out-of-band limits will be considered following a determination of whether the GLONASS frequency plan can be revised or reconfigured. However, the aviation community is in agreement that the same MES out-of-band emission limits of -70 dBW/1MHz broadband and -80 dBW narrowband (i.e., bandwidth less than 600 Hz) should also apply to any portion of the GLONASS operation band below 1610 MHz.

APPENDIX B - MEETING DATES & LOCATIONS OF DRAFTING GROUP 2B

DATE	LOCATION
2/16/93	FCC, Rm. 856
2/25/93	FCC, Rm. 856
3/2/93	FCC, Rm. 856
3/5/93	COMSAT, Early Bird Room, 950 L'Enfant Plaza, S.W.
3/11/93	FCC, Training Room, 2000 L
3/15/93	COMSAT, 8th Fl. Conf. Rm., 950 L'Enfant Plaza, S.W.
3/18/93	FCC, Rm. 856
3/23/93	FCC, Rm. 856
3/30/93	FCC, Rm. 856

APPENDIX A - PARTICIPANTS OF DRAFTING GROUP 2B

NAME	ORGANIZATION
Melvin Barmat	Jansky/Barmat Telecom
Richard Barnett	Telecom Strategies for TRW
Stephen Baruch	Leventhal, Senter & Lerman for TRW
Jeff Binckes	COMSAT Moblie Communications
William Borman	Motorola, Inc.
Larry Chesto	Aeronautical Radio, Inc.
Steve Clark	Motorola, Inc.
James Danaher	3S Navigation
Robert Erlandson	Rockwell-Collins Commercial Avionics
Robert Frazier	Federal Aviation Administration
Guy Gooch	Rockwell
John Hatlelid	Motorola, Inc.
John Knudsen	Motorola Satellite Communcations
Ron Lepkowski	Constellation Communications
Philip Malet	Steptoe & Johnson for Motorola
Alfred Mamlet	Steptoe & Johnson for Motorola
Gerald Munson	Motorola Satellite Communcations
Harry Ng	Federal Communications Commission
Sam Nguyen	COMSAT Moblie Communications
Bruno Pattan	Federal Communications Commission
Wilbur Pritchard	W.L. Pritchard & Co., Inc.
Ed Reinhart	Consultant for NASA LeRC
Raul Rodriguez	Leventhal, Senter & Lerman for TRW
Linda Sadler	Rockwell
Tom Sullivan	Atlantic Research Corp. for AMSC
Leslie Taylor	LTA for LQSS
Victor Toth	Victor J. Toth for CELSAT
Michael Ward	American Mobile Satellite Corporation
Bob Weiblen	Weiblen for CELSAT
Jack Wengryniuk	COMSAT Laboratories
Chuck Windett	Loral Qualcomm Satellite Services

Attachment C
to MSSAC-42.7 (Rev.5)

(also numbered as Doc. IWG2-75
(Rev.4) and MSSAC-42.6 (Rev.1))

Report of Drafting Group 2C

Sharing with Services other than ARNS and RAS

April 1993

Sharing with Services other than ARNS and RAS
Report of Drafting Group 2C

Sharing with Services other than ARNS and RAS
Report of Drafting Group 2C

1.0 Introduction

The purpose of this report is to survey the segments of the 1610-1626.5 MHz L-band and 2483.5-2500 MHz S-band proposed for allocation to the mobile satellite service (MSS), to identify other services using or planning to use these frequencies or contiguous bands, and to assess the practicality of MSS sharing with them. The other services are tabulated in Table 1. Several of these services are sufficiently complex to justify dedicated reports and are addressed elsewhere, i.e., Radio Astronomy and Radio Navigation Services. This report deals with all the other services.

Table 1 Frequency Sharing by MSS with Other Services

	L-Band	S-Band
into MSS	FS Primary (FN 730) FS Secondary (FN 727) RLS Swedish Radars	ITFS/MMDS ISM FS (Part 94) MS (Part 90) BAS (Part 74) BSS Insat & Arabsat (out of band) MS wireless (Radio LANS, medical t/m, etc.) U.S. <2483.5 MHz World wide (2400-2500 MHz)
by MSS	FS Primary (FN 730) FS Secondary (FN 737) RLS Swedish Radars	ITFS/MMDS FS (Part 94) MS (Part 90) BAS (Part 74) RLS French radar BSS Insat & Arabsat (out of band) MS Wireless (Radio LANS, medical t/m, etc.) U.S. <2483.5 MHz World wide (2400-2500 MHz)

2.0 Conclusions and Recommended Rules

2.1 IWG2 finds that existing operations in the band 1610-1626.5 MHz (other than RAS and ARNS, covered elsewhere) will not cause harmful interference to MSS operations. The IWG2 further finds that MSS operations will not cause harmful interference to any existing services in this band (other than RAS and ARNS, dealt with elsewhere). Accordingly, no rule changes or modifications are required.

2.2 The IWG2 finds that there will be no interference from MSS into the ITFS/MMDS services, but that out of band emissions from the channels just above 2500 MHz in those services will cause harmful interference with MSS mobile terminals at distances up to several kilometers from a ITFS/MMDS transmitter. The IWG2 recommends that the FCC initiates NPRN to tighten out of band emissions to a level of at least 90 dB below the carrier level at an offset between 1.25 MHz and 2.0 MHz below 2500 MHz.

2.3 Insofar as the use of S-band is concerned, the IWG2 concludes that MSS could cause harmful interference to terrestrial fixed microwave and mobile radio services under some circumstances. The IWG2 expects that these circumstances will be infrequent and subject to successful coordination with systems operating in accordance with the PFD limit (RR2566). The IWG2 also notes that there is no inherent technical reason why terrestrial fixed services need to operate in the lower end of the microwave spectrum, whereas there are well known and fundamental reasons why the mobile services, using omnidirectional antennas, need to use these frequencies. Therefore it is IWG2's conclusion that the FCC should take all steps necessary to have existing domestic systems moved to higher carrier frequencies. The IWG2 urges the FCC to work with U.S. and foreign administrations and international agencies to achieve the same ends throughout the world.

2.4 The IWG2 concludes that the Swedish radars operating in the L-band, because of their sparse locations and pulsed operation, will not cause harmful interference to MSS operators with well designed receivers, nor will MSS operations interfere with them. The IWG2 expects that the situation will be similar for the French radars operating in the S-band.

2.5 The measurements conducted by NTIA reveal that, in a cumulative environment, there may be a significant ISM interference noise floor in populated areas. An MSS user terminal operating in such areas may experience varying levels of cumulative interference that may exceed the thermal noise level of the receiver. The IWG2 noted that this situation could be acceptable to operators using terrestrial cellular links in metropolitan areas, but may affect MSS operations in this band in other service scenarios. The FCC should take decisive action to tighten the permitted radiation from ISM devices and to restrict the occupied bandwidths. A copy of the IWG2 report should be associated with ET docket #91-313 which addresses harmonization of Part 18 of the FCC rules with the international standards for ISM equipment.

2.6 Except as otherwise mentioned, under the broad categories of fixed, mobile, and broadcast auxiliary services, the IWG2 did not find any services likely to cause interference with MSS or to be interfered with. Out-of-band emissions from BAS and BSS and the broadcast satellite service were deemed to be inconsequential and sporadic problems with the fixed and mobile services should be easy to coordinate.

3.0 Sharing with Services other than RAS and ARNS in the L-Band

3.1 Overview

In accordance with the decisions reached at WARC-92, the Commission has proposed (1) a primary MSS allocation in the Earth-to-space direction for the 1610-1626.5 MHz band; and (2) a secondary MSS allocation in the space-to-Earth direction for the 1613.8-1626.5 MHz band. The IWG2 has considered the other services allocated in the 1610-1626.5 MHz band (both domestically and internationally) in order to evaluate any sharing concerns associated with the proposed MSS allocations.